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(54) **FILAMENT WINDING APPARATUS**

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USPC 242/437, 438, 439.1, 439.2, 439.5, 444, 242/444.4
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,213,894 A *	10/1965	Etchison, Jr. et al.	......	242/439.1
3,245,624 A *	4/1966	Meyers et al.	....	242/444
4,010,054 A *	3/1977	Bradt	....	156/173

(Continued)

FOREIGN PATENT DOCUMENTS

JP	05-254027	10/1993
JP	05254027 A	10/1993

(Continued)

OTHER PUBLICATIONS

English language translation of international preliminary report on patentability dated Apr. 16, 2013 issued in corresponding PCT application PCT/JP2011/071531.

(Continued)

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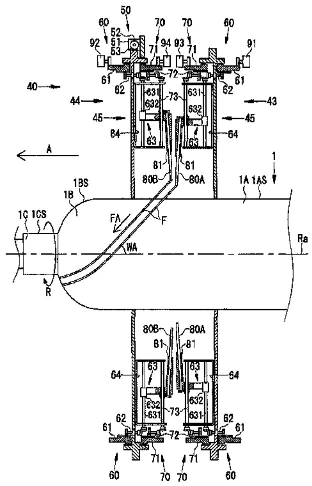
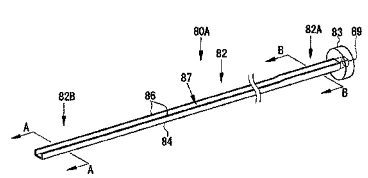
(57) **ABSTRACT**

A filament winding apparatus in which a fiber bundle easily passes through a fiber supplying guide. The filament winding apparatus winds a fiber bundle around a liner, and includes a plurality of fiber supplying guides each supplying a fiber bundle to the liner. Each of the fiber supplying guides includes a bottom portion that guides a wide surface of the fiber bundle, side portions respectively disposed along both sides of the bottom portion, and an opening portion formed between the side portions.

3 Claims, 9 Drawing Sheets





(51) **Int. Cl.**

B29C 70/32	(2006.01)
B29C 53/60	(2006.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,028,164	A *	6/1977	Montagut	156/173
5,897,729	A *	4/1999	Bikson et al.	156/172
6,431,490	B1 *	8/2002	Monget et al.	242/444
6,540,171	B2 *	4/2003	Yasui et al.	242/437
6,601,793	B2 *	8/2003	Yasui et al.	242/472.8
7,300,014	B2 *	11/2007	Allen	242/439.5
7,815,141	B2 *	10/2010	Uozumi et al.	242/445.1
8,105,454	B2 *	1/2012	Uozumi et al.	156/175
2006/0175454	A1 *	8/2006	Allen	242/439.5
2009/0038759	A1	2/2009	Uozumi et al.	
2009/0065630	A1	3/2009	Moore, III	
2009/0127373	A1	5/2009	Uozumi et al.	242/436
2010/0032510	A1	2/2010	Tanigawa et al.	242/430

FOREIGN PATENT DOCUMENTS

JP	2007-190697	A	8/2007
JP	2008296411	A	12/2008
JP	2009-119732		6/2009
JP	2010-005831		1/2010
JP	2010005831	A	1/2010
JP	2010-036461		2/2010
WO	99/65810	A1	12/1999

OTHER PUBLICATIONS

Extended European Search Report issued in corresponding application EP 11828899.2, dated Mar. 30, 2015.

* cited by examiner

Fig. 1

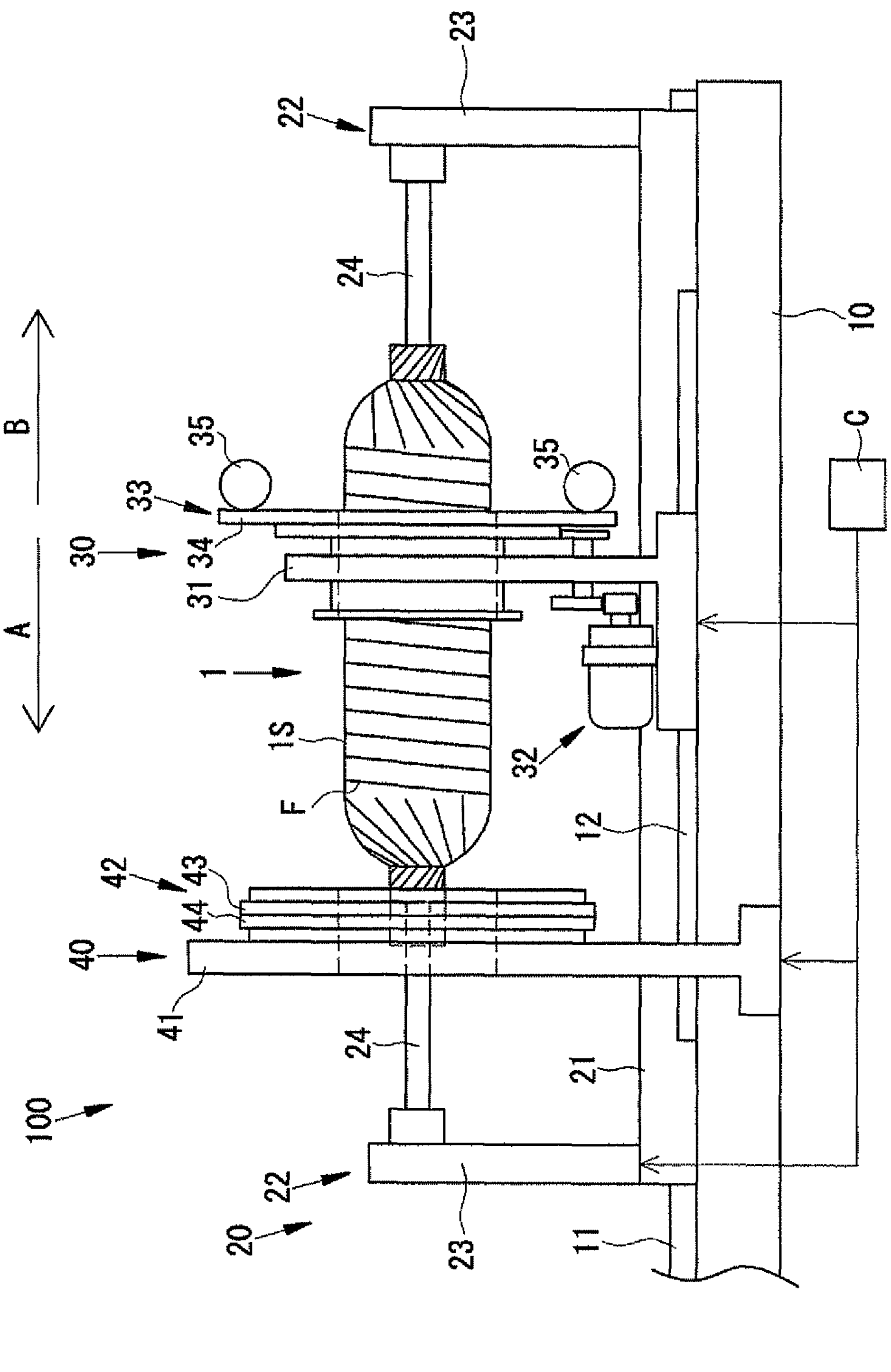

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Fig. 2

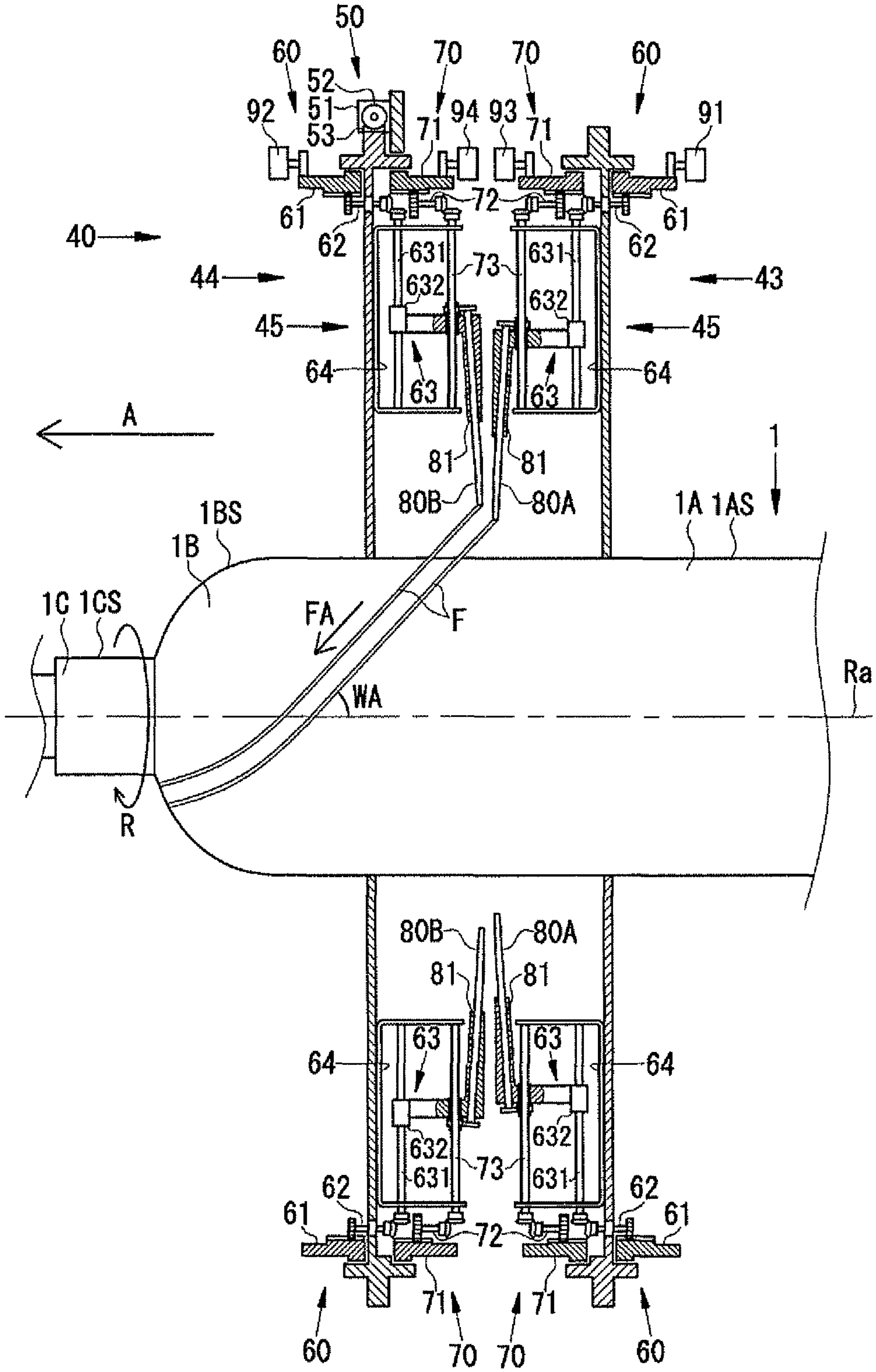
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Fig. 3

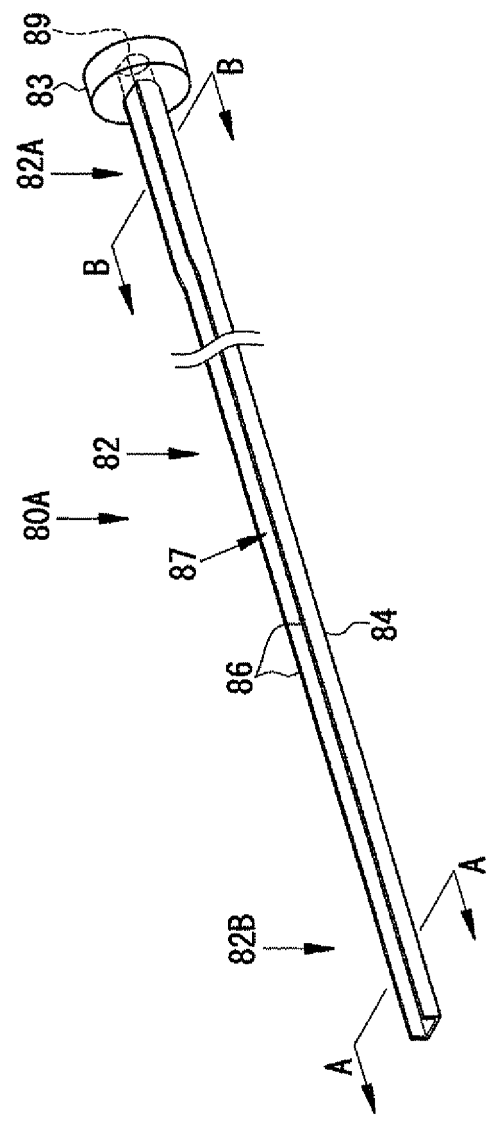
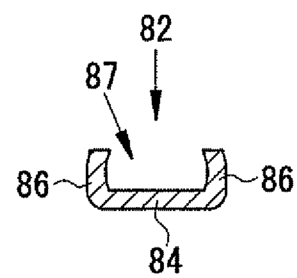


Fig. 4

(A)



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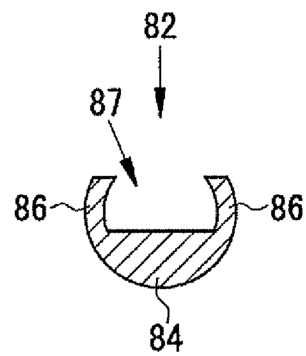

Fig. 5

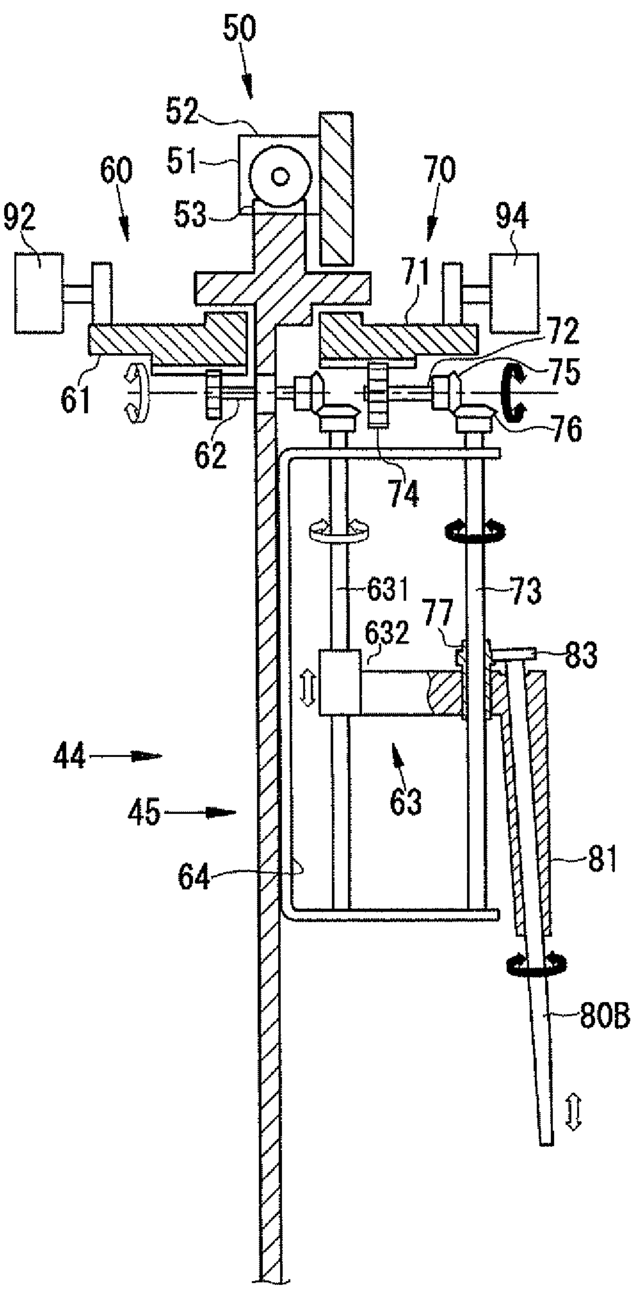

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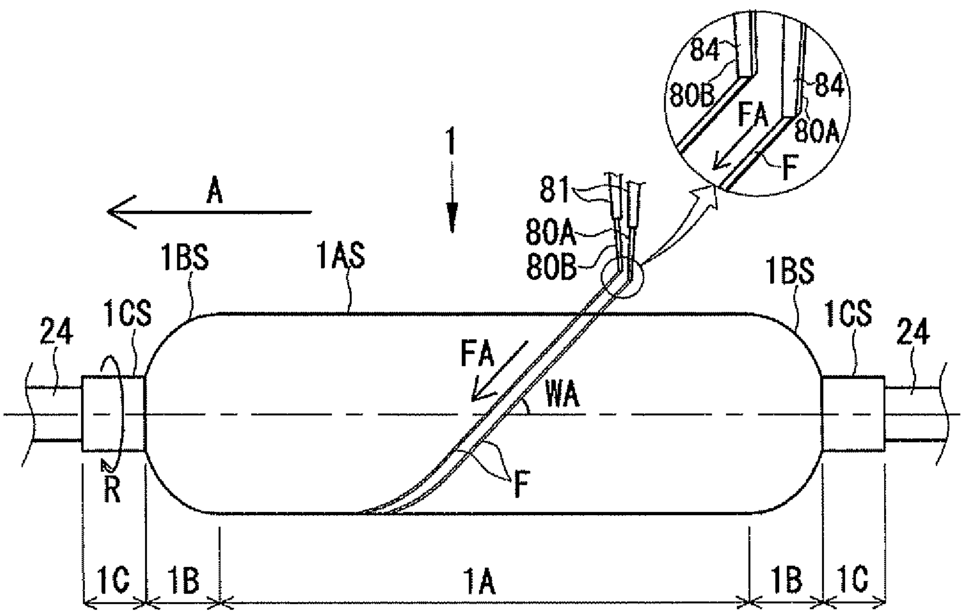
Fig. 6

(A)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(B)

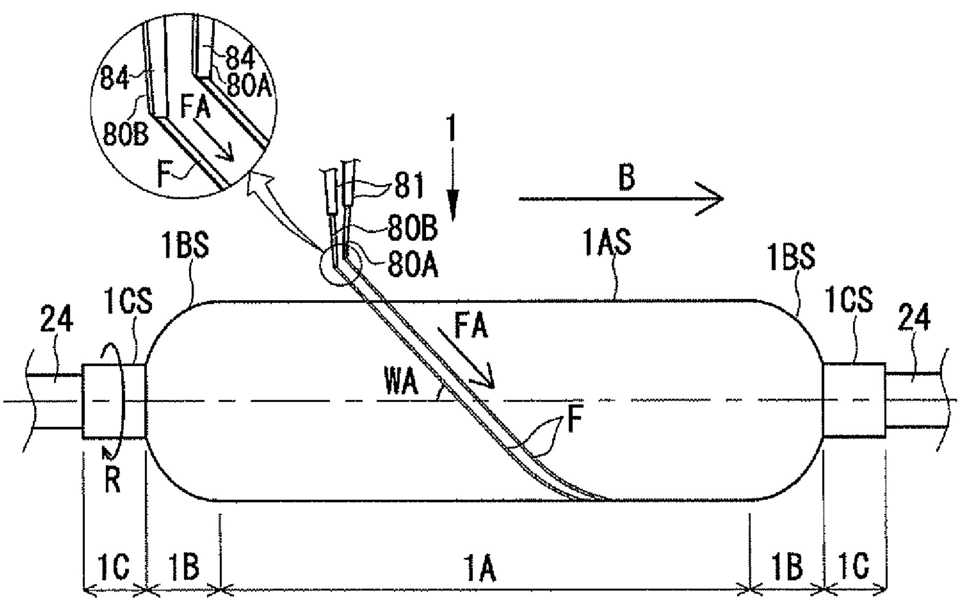
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Fig. 7

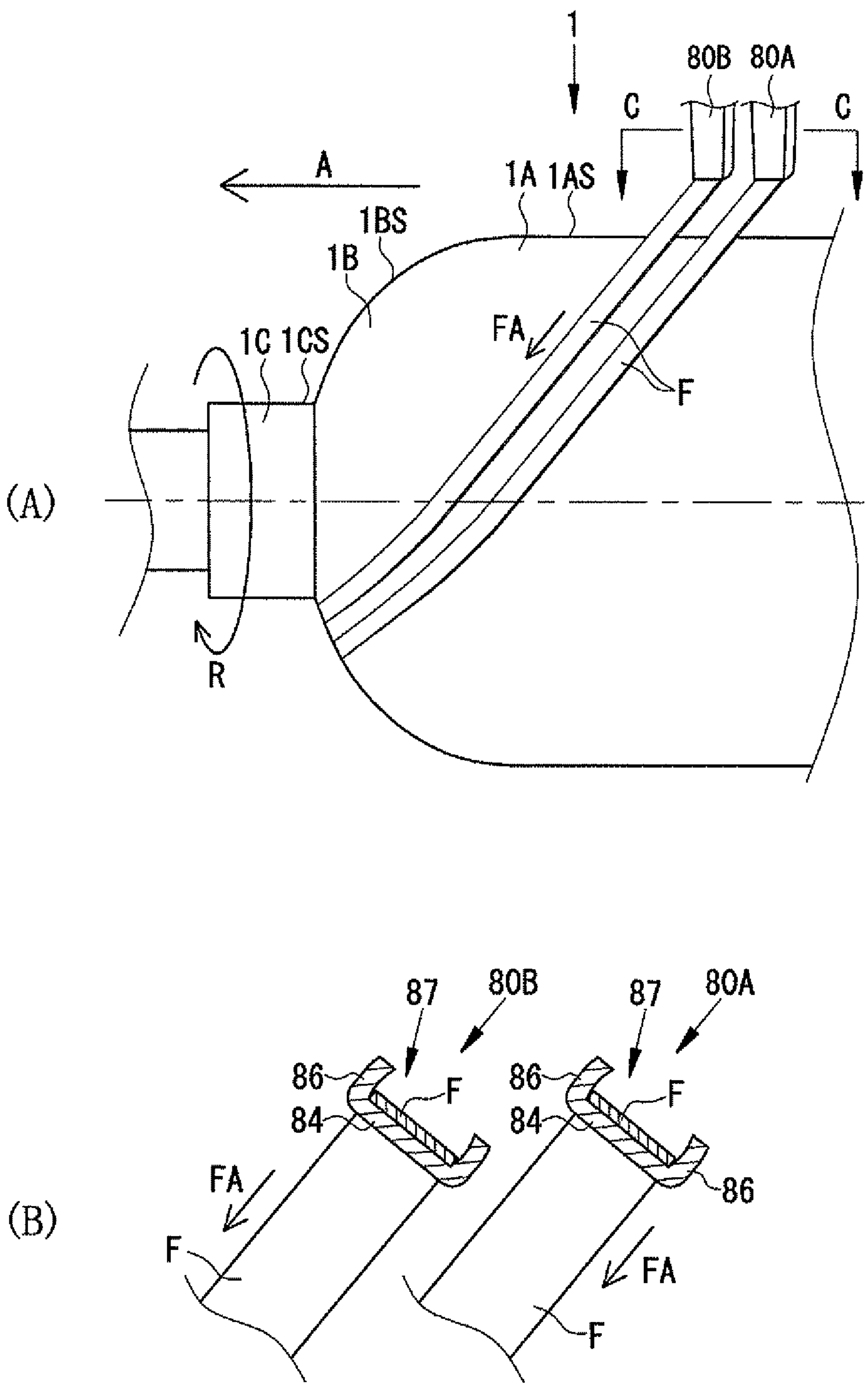
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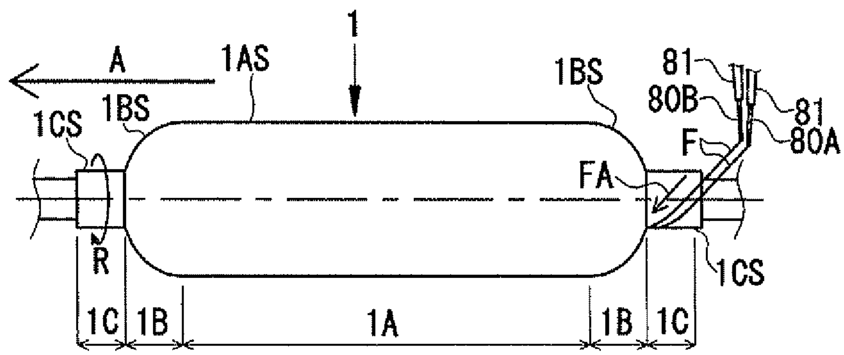
Fig. 8

(A)



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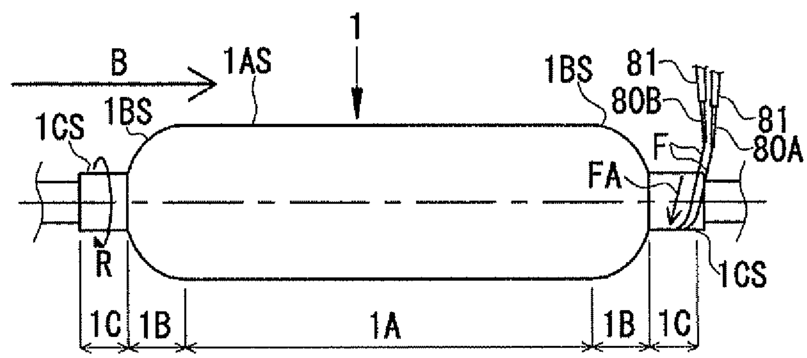

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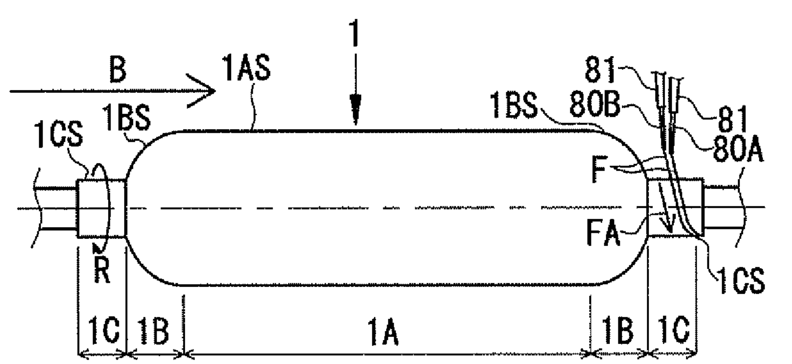

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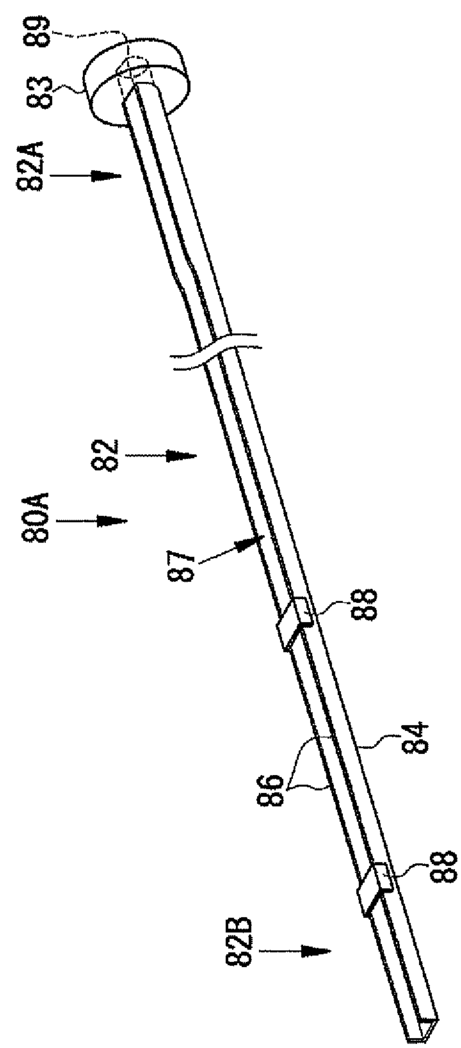
Fig. 9



FILAMENT WINDING APPARATUS

CROSS REFERENCE TO RELATED APPLICATIONS

This application is a national stage of international application PCT/JP2011/071531, filed on Sep. 21, 2011, and claims the benefit of priority under 35 USC 119 of Japanese application 2010-217332, filed on Sep. 28, 2010, which are incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a filament winding apparatus.

BACKGROUND ART

A filament winding apparatus has been known that includes a hoop winding device and a helical winding device and is configured to wind fiber bundles around a liner by performing hoop winding and helical winding alternately and repeatedly on the liner, thereby forming a reinforcement layer.

In the helical winding, the position of the helical winding device is fixed, and fiber bundles are wound around the liner by moving the liner in the direction of a rotation axis while the liner is rotated. The fiber bundles are supplied to the liner from fiber supplying guides disposed in the helical winding device. A filament winding apparatus has been also known that includes a first guide unit and a second guide unit, each of which includes a plurality of fiber supplying guides disposed radially in the helical winding device, and thus can simultaneously wind a plurality of fiber bundles (for example, Patent Document 1).

RELATED ART DOCUMENT

Patent Document

Patent document 1: Japanese Unexamined Patent Application Publication No. 2010-36461.

DISCLOSURE OF THE INVENTION

Problems to be Solved by the Invention

As described in Paragraph 0034 of Patent Document 1, the fiber supplying guide of the helical winding device of Patent Document 1 has a tapered shape that tapers from a base end portion toward a distal end portion. A flat guide hole penetrates the inside of the fiber supplying guide from the base end portion to the distal end portion so as to allow a fiber bundle to pass through. As preparation before actuating a helical winding device, a fiber bundle needs to be made to pass through each of the fiber supplying guides manually, and the leading end of each fiber bundle needs to be secured to the outer peripheral surface of the liner.

However, the operation to make each of the fiber bundles, one by one, pass through a thin, long, and flat guide hole is not easy and is a troublesome work. Further, the number of the fiber supplying guides of a helical winding device is large (for example, 180). Accordingly, it takes a long time to make fiber bundles pass through all the fiber supplying guides of the helical winding device.

Further, processing, such as providing a fiber supplying guide with a tapered shape that tapers from a base end portion

toward a distal end portion and forming a flat guide hole penetrating from a base end portion toward a distal end portion inside the fiber supplying guide, is troublesome. Accordingly, the manufacturing cost of such a fiber supplying guide is high, and thus the manufacturing cost of the filament winding apparatus is high.

SUMMARY OF THE INVENTION

The present invention is made to solve the above-mentioned problem. The first object of the present invention is to provide a filament winding apparatus in which a fiber bundle can be easily made to pass through a fiber supplying guide. The second object of the present invention is to develop a fiber supplying guide that is manufactured easily at low cost, thereby providing a filament winding apparatus at a low price.

Means of Solving the Problems

The problems to be solved by the present invention are described above, and next, means for solving the problems will be described.

Specifically, a first invention is a filament winding apparatus configured to wind a fiber bundle around a liner, comprising a plurality of fiber supplying guides each being configured to supply a fiber bundle to the liner. Each of the fiber supplying guides includes a bottom portion that guides a wide surface of the fiber bundle, side portions respectively disposed along both sides of the bottom portion, and an opening portion formed between the side portions.

A second invention is the filament winding apparatus of the first invention that may further include a driving unit configured to make the fiber supplying guides rotate about an axis, and a controller configured to change an orientation of each of the fiber supplying guides by controlling the driving unit. The controller may change an orientation of the fiber supplying guide in accordance with a winding angle and winding direction in which the fiber bundle is wound around the liner, in such a manner that the fiber bundle does not fall off the fiber supplying guide.

The third invention is the filament winding apparatus of the first or the second invention in which an anti-falling member that partially covers the opening portion may be disposed detachably.

Effects of the Invention

As the effect of the present invention, the following effects are accomplished.

According to the first invention, the fiber supplying guides each includes the bottom portion that guides the wide surface of the fiber bundle, the side portions respectively disposed along both sides of the bottom portion, and the opening portion formed between the side portions. Accordingly, a fiber bundle needs not to pass through a guide hole that penetrates from a base end portion to a distal end portion, and thus a fiber bundle can be easily made to pass through the fiber supplying guide. Further, the fiber supplying guide of the present invention can be manufactured easier and at lower cost compared to the fiber supplying guide in which a guide hole penetrating from a base end portion to a distal end portion is formed.

According to the second invention, the orientation of the fiber supplying guide is changed in accordance with the winding angle and the winding direction in which the fiber bundle is wound around the liner, in such a manner that the fiber bundle does not fall off the fiber supplying guide. Accordingly, even if tension is applied on the fiber bundles, the fiber bundles do not fall off the fiber supplying guide. Therefore, the fiber bundles can be wound around the liner while sufficient tension is applied to the fiber bundles.

According to the third invention, the anti-falling member configured to partially cover the opening portion is disposed detachably. Accordingly, even while the winding is stopped and thus no tension is applied to the fiber bundles during the maintenance of the apparatus for example, the fiber bundles can be prevented from falling off the fiber supplying guide.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram illustrating an FW apparatus **100** according to an embodiment of the present invention.

FIG. **2** is a schematic diagram illustrating a first helical head **43** and a second helical head **44** that configure a helical winding device **40**.

FIG. **3** is a perspective view of a fiber supplying guide **80**A.

FIGS. **4**A and **4**B are cross sectional views taken along a line A-A and a line B-B in FIG. **3**.

FIG. **5** is a schematic view of a guide supporting device **45** that configures the first helical head **43** and the second helical head **44**.

FIGS. **6**A and **6**B are side views showing the state where fiber bundles F are wound in helical winding around an outer peripheral surface **1**AS of the first cylindrical portion **1**A.

FIG. **7**A is a side view showing the state where fiber bundles F are wound in helical winding around the outer peripheral surface **1**AS of the first cylindrical portion **1**A.

FIG. **7**B is a cross-sectional view taken along a line C-C in FIG. **7**A.

FIGS. **8**A, **8**B and **8**C are side views showing the state where the winding direction of fiber bundles F is switched while the fiber bundles F is wound in helical winding around an outer peripheral surface **1**CS of a second cylindrical portion **1**C.

FIG. **9** is a perspective view showing another example of the fiber supplying guide **80**A.

BEST MODE FOR CARRYING OUT THE INVENTION

Next, an embodiment of the invention will be described with reference to the drawings.

[Embodiment 1]

First, the entire configuration of a filament winding apparatus **100** according to Embodiment 1 of the present invention will be described with reference to FIG. **1**. Hereafter, the filament winding apparatus **100** is described while being abbreviated to the FW apparatus **100**.

FIG. **1** is a side view of the FW apparatus **100**. The FW apparatus **100** is an apparatus that winds fiber bundles F around the periphery of a liner **1** by performing hoop winding and helical winding alternately and repeatedly on the liner **1**.

Arrows A and B shown in FIG. **1** indicate the front-rear direction of the FW apparatus **100** and the conveyance direction of the liner **1** in the helical winding. In the helical winding, in order to make the liner **1** reciprocate in the front-rear direction of the FW apparatus **100**, the liner **1** is conveyed in the direction indicated by the arrow A and conveyed in the direction indicated by the arrow B. In the following description, the front side in the direction to which the liner **1** is conveyed is defined as the front side of each of the liner **1** and the FW apparatus **100**, and the other direction is defined as the rear side. That is, the front side and the rear side of the FW apparatus **100** are switched depending on the conveyance direction of the liner **1**. When the liner **1** is conveyed in the direction indicated by the arrow A, the left side in FIG. **1** is defined as the front side of each of the liner **1** and the filament winding apparatus. Furthermore, when the conveyance direction of the liner **1** is switched, and thus the liner **1** is conveyed in the direction indicated by the arrow B, the right side in FIG. **1** is defined as the front side of each of the liner **1** and the FW apparatus **100**.

The liner **1** is an approximately-tubular hollow container made of, for example, a high-strength aluminum material or a polyimide type resin. Through winding of fiber bundles F around an outer peripheral surface **1**S of the liner **1**, the pressure resistant property of the liner **1** can be improved. Thus, the liner **1** serves as a base member forming a pressure resistant container.

The FW apparatus **100** mainly includes a main base **10**, a liner conveyance device **20**, a hoop winding device **30**, a helical winding device **40**, and a controller C. The main base **10** forms the foundation of the FW apparatus **100**. The main base **10** is provided with, on an upper portion thereof, the liner conveyance device rail **11**. On the liner conveyance device rail **11**, the liner conveyance device **20** is mounted. At the upper portion of the main base **10**, the hoop winding device rail **12** is disposed in parallel to the liner conveyance device rail **11**. On the hoop winding device rail **12**, the hoop winding device **30** is mounted. With this configuration, the liner conveyance device **20** and the hoop winding device **30** are movable relative to the main base **10**. The helical winding device **40** is secured to the main base **10**.

The liner conveyance device **20** makes the liner **1** rotate about a rotation axis Ra (refer to FIG. **2**) along the front-rear direction of the FW apparatus **100**, and conveys the liner **1** in the front-rear direction of the FW apparatus **100**. The liner conveyance device **20** mainly includes a base **21** and liner supporting sections **22**. The actuation of the liner conveyance device **20** is controlled by the controller C.

The base **21** includes a pair of liner supporting sections **22**. Each of the liner supporting sections **22** includes a liner supporting frame **23** and a supporting shaft **24**. The liner supporting frame **23** extends upward from the base **21**. The supporting shaft **24** extends from the liner supporting frame **23** along the front-rear direction of the FW apparatus. The supporting shaft **24** is rotated in one direction about its axis by a not-shown driving mechanism. The supporting shafts **24** respectively support both ends of the liner **1** so as to rotate the liner **1**. With this configuration, the liner conveyance device **20** makes the liner **1** rotate via the supporting shafts **24** serving as a rotating shaft Ra, and conveys the liner **1** in the front-rear direction of the FW apparatus **100**.

The hoop winding device **30** winds a fiber bundle F in hoop winding around the outer peripheral surface **1**S of the liner **1**. In the hoop winding, the fiber bundle F is wound around the peripheral surface **1**S of the liner **1** with a winding angle of the fiber bundle F with respect to the central axis of the liner **1** being approximately 90°. The hoop winding device **30** mainly includes a base **31**, a power mechanism **32**, and a hoop winding support device **33**. The actuation of the hoop winding device **30** is controlled by the controller C.

On the base **31**, the power mechanism **32** and the hoop winding support device **33** are mounted. The hoop winding support device **33** includes a winding support table **34** and a bobbin **35**. At the center of the winding support table **34**, a space through which the liner **1** is inserted is provided. The bobbin **35** is disposed on the winding support table **34**, and configured to supply a fiber bundle F to the outer peripheral surface **1**S of a liner **1**. The power mechanism **32** is configured to make the hoop winding support device **33** rotate about the central axis of the liner **1**.

In the hoop winding, the position of the liner **1** is fixed, and the hoop winding support device **33** is rotated about the central axis of the liner **1** while the hoop winding device **30** moves along a direction of the central axis of the liner **1**. Thus, the hoop winding is performed. It is to be noted that, by adjusting the moving speed of the hoop winding device **30** and the rotating speed of the winding support table **34**, the winding form of the fiber bundles F can be changed freely.

The helical winding device **40** winds the fiber bundles F in helical winding around the outer peripheral surface **1**S of the liner **1**. In the helical winding, the fiber bundles F are wound around the outer peripheral surface **1**S of the liner **1** so that the winding angle WA (refer to FIG. **2**) of the fiber bundle F is a predetermined value (for example, 0 to 60 degrees). The helical winding device **40** mainly includes a base **41** and a helical winding support device **42**. The actuation of the helical winding device **40** is controlled by the controller C.

On the base **41**, the helical winding support device **42** is mounted. The helical winding support device **42** includes a first helical head **43** as a first guide unit and a second helical head **44** as a second guide unit. To the first helical head **43** and the second helical head **44**, fiber bundles F are supplied from a plurality of bobbins (not-shown), and then the fiber bundles F are guided to the outer peripheral surface **1**S of the liner **1** (refer to FIG. **2**).

In the helical winding, the helical winding device **40** is fixed, and the liner **1** is conveyed in the direction of the central axis Ra while being rotated by the liner conveyance device **20**. Thus, the helical winding is performed. It is to be noted that, by adjusting the conveying speed and rotating speed of the liner **1**, the winding form of the fiber bundles F can be changed freely.

Next, the first helical head **43** and the second helical head **44** that configure the helical winding device **40** are further described in detail. FIG. **2** is a side view showing the first helical head **43** and the second helical head **44**. An arrow A shown in the drawing indicates the conveyance direction of the liner **1**. Furthermore, an arrow R indicates the rotation direction of the liner **1**.

As shown in FIG. **2**, the first helical head **43** and the second helical head **44** are adjacently arranged in the conveyance direction of the liner **1**. The first helical head **43** and the second helical head **44** include fiber supplying guides **80**A and **80**B configured to guide fiber bundles F to the outer peripheral surface **1**S of the liner **1**. The first helical head **43** includes a plurality of fiber supplying guides **80**A that are arranged radially and are approximately perpendicular to the central axis Ra of the liner **1**. The second helical head **44** includes a plurality of fiber supplying guides **80**B that are arranged radially and are approximately perpendicular to the central axis Ra of the liner **1**. Specifically, the fiber supplying guides **80**A and **80**B provided respectively to the first helical head **43** and the second helical head **44** are arranged in two rows in the conveyance direction of the liner **1**.

The first helical head **43** and the second helical head **44** include a plurality of guide supporting devices **45**. Each of the guide supporting devices **45** respectively supports the fiber supplying guide **80**A and the fiber supplying guide **80**B. Each of the guide supporting devices **45** respectively supports the fiber supplying guides **80**A and **80**B in such a manner that the fiber supplying guides **80**A and **80**B can extend and contract in a direction approximately perpendicular to the central axis Ra and that the fiber supplying guides **80**A and **80**B are rotatable around its axis. The first helical head **43** is configured in such a manner that all fiber supplying guides **80**A can be extended or contracted at the same amount and rotated simultaneously, and the second helical head **44** is also configured in such a manner that all fiber supplying guides **80**B can be extended or contracted at the same amount and rotated simultaneously. Further, the fiber supplying guides **80**A of the first helical head **43** and the fiber supplying guides **80**B of the second helical head **44** can be adjusted each other to extend, contract, and rotate by different amounts.

Here, the fiber supplying guides **80**A and **80**B of the present embodiment will be described with reference to FIG. **3** and FIGS. **4**A and **4**B. Since the fiber supplying guides **80**A and **80**B of the present embodiment have the same configuration, description is given for the fiber supplying guide **80**A.

FIG. **3** is a perspective view of the fiber supplying guide **80**A. FIGS. **4**A and **4**B are cross sectional views taken along a line A-A and a line B-B in FIG. **3**. As shown in FIG. **3**, the fiber supplying guide **80**A mainly includes a fiber supplying guide main body **82** and a gear **83**. The fiber supplying guide main body **82** guides a fiber bundle F supplied from the bobbin (not shown) from a base end portion **82**A to a distal end portion **82**B. The fiber supplying guide main body **82** includes a bottom portion **84** and side portions **86**. As shown in FIG. **4**A and FIG. **4**B, the cross sectional shape of the fiber supplying guide **80**A in the direction orthogonal to the axial direction is an approximately square U shape. The bottom portion **84** of the fiber supplying guide **80**A has a flat surface on which the wide surface of the fiber bundle F is guided. The side portions **86** are disposed respectively on both sides of the bottom portion **84** and prevent the guided fiber bundle F from falling off. An opening portion **87** is formed between both the side portions **86**.

Further, as shown in FIG. **3** and FIG. **4**B, especially at the base end portion **82**A, the side portion **86** is high and is curved toward the inside. The lower part of the bottom portion **84** has a semicircular shape. Namely, as shown in FIG. **4**B, the cross-sectional shape at the base end portion **82**A is a shape of a partially omitted circle which is formed by the bottom portion **84** and the side portions **86**. This base end portion **82**A is axially supported rotatably by the guide supporting member **81** of the guide supporting device **45** mentioned later. Thus, the fiber supplying guide **80**A is axially supported rotatably by the guide supporting member **81**.

The gear **83** meshes with a driving gear **77** disposed on a rotation mechanism **70** of the guide supporting device **45** mentioned later and makes the fiber supplying guide **80**A rotate about the axis. As shown in FIG. **3**, an insertion hole **89** is formed at the central portion of the gear **83**. By press fitting the base end portion **82**A of the fiber supplying guide main body **82** into the insertion hole **89**, the gear **83** is secured to the fiber supplying guide main body **82**. Further, the fiber bundle F supplied from the bobbin (not-shown) is made to pass through the insertion hole **89**, and the fiber bundle F is guided to the fiber supplying guide main body **82**.

Thus, the fiber supplying guide main body **82** of the fiber supplying guide **80**A is consisted of the bottom portion **84** and the side portions **86**, and the opening portion **87** is provided. Accordingly, when passing through the fiber supplying guide **80**A, a fiber bundle F may first pass through the insertion hole **89**, and then, be fitted through the opening portion **87**. Therefore, the fiber bundle F needs not to pass through a guide hole that penetrates from the base end portion to the distal end portion, and thus a fiber bundle F can be easily made to pass through the fiber supplying guide **80**A.

Further, the fiber supplying guide **80**A can be processed by a press-processing means and the like. Accordingly, manufacturing is easier and thus the cost is lower in comparison with the conventional fiber supplying guide in which a guide hole is formed from a base end portion to a distal end portion.

By providing the fiber supplying guides **80**A and **80**B with such a configuration to the first helical head **43** and the second helical head **44**, each of the first helical head **43** and the second helical head **44** can guide a plurality of fiber bundles F simultaneously to the outer peripheral surface **1**S of the liner **1**. In the FW apparatus **100** according to this embodiment, the first helical head **43** includes 90 fiber supplying guides **80**A, and the second helical head **44** includes 90 fiber supplying guides **80**B. Therefore, it is possible to perform the helical winding by guiding a total of 180 fiber bundles F simultaneously to the outer peripheral surface **1**S of the liner **1**.

Moreover, the FW apparatus **100** according to this embodiment includes a driving unit **50** that drives the second helical head **44** in the circumferential direction of the liner **1** about the rotation axis Ra of the liner **1**. The drive unit **50** includes a worm gear **52** rotated by an electric motor **51** and a rack gear **53** secured to the second helical head **44**. The driving unit **50** drives the second helical head **44** with the rotation power of the electric motor **51**. Thus, the driving unit **50** can drive the second helical head **44** and adjust the phase difference between the first helical head **43** and the second helical head **44**.

Next, with reference to FIG. **5**, description is given in detail to the guide supporting device **45** that supports the fiber supplying guide **80**A of the first helical head **43** and the fiber supplying guide **80**B of the second helical head **44**. The guide supporting device **45** is common between the first helical head **43** and the second helical head **44**, and FIG. **5** shows the guide supporting device **45** disposed on the second helical head **44**.

As shown in FIG. **5**, the guide supporting devices **45** are arranged radially to the first helical head **43** and the second helical head **44** in the number corresponding to the number of each of the fiber supplying guides **80**A and **80**B, and each of the guide supporting devices **45** includes a movement mechanism **60** and a rotation mechanism **70**. Each of the fiber supplying guides **80**A and **80**B is axially supported rotatably by the guide supporting member **81**. In the drawing, a white arrow indicates the operation direction of the members that construct the movement mechanism **60**, and a black arrow indicates the operation direction of the members that construct the rotation mechanism **70**.

The movement mechanism **60** changes an amount of extension or contraction of each of the fiber supplying guides **80**A and **80**B in the direction approximately perpendicular to the central axis Ra of the liner **1**. The movement mechanism **60** mainly includes a rotation tube **61**, an intermediate shaft **62**, and a ball screw **63**. The movement mechanism **60** of the first helical head **43** is driven by an electric motor **91** serving as a driving unit that changes an amount of extension or contraction of the fiber supplying guides **80**A. The movement mechanism **60** of the second helical head **44** is driven by an electric motor **92** serving as a driving unit that changes an amount of extension or contraction of the fiber supplying guide **80**B.

The rotation tube **61** is an annular member having an internal gear on its inner peripheral surface. The rotation tube **61** is coaxially arranged around the central axis Ra of the liner **1**, and rotated by the electric motors **91** and **92**.

The intermediate shaft **62** transmits the rotation of the rotation tube **61** to a spiral shaft **631** that forms the ball screw **63**. A pinion gear disposed on the one end of the intermediate shaft **62** meshes with the internal gear of the rotation tube **61**. Moreover, a bevel gear disposed on the other end of the intermediate shaft **62** meshes with the bevel gear of the spiral shaft **631**.

The ball screw **63** converts the rotating motion of the intermediate shaft **62** into the movement motion of the guide supporting member **81**. The ball screw **63** mainly includes a spiral shaft **631** and a ball nut **632**.

The spiral shaft **631** is rotated by the intermediate shaft **62**. On the outer peripheral surface of the spiral shaft **631**, a groove having a cross-sectional shape of an arc is formed to define a spiral form. The spiral shaft **631** is supported rotatably by an annular member **64** having a cross-sectional shape of a letter "C".

The ball nut **632** is a tubular member that is fit externally around the spiral shaft **631**. On the inner peripheral surface of the ball nut **632**, a groove having a cross-sectional shape of an arc is formed to define a spiral form. Further, the ball nut **632** is inserted and secured in a through-hole provided to the guide supporting member **81**. The groove cut in the inner periphery surface of the ball nut **632** is arranged to face the groove cut in the outer periphery surface of the spiral shaft **631**, thereby forming a spiral space having a circular cross-sectional view.

In the spiral space mentioned above, a steel ball is provided. The steel ball is held between the groove formed in the spiral shaft **631** and the groove formed in the ball nut **632**. Since a plurality of steel balls are provided in the spiral space, the ball nut **632** does not become rickety.

With this configuration, the movement mechanism **60** transmits the driving power of one of the electric motors **91** and **92** to the spiral shaft **631** via the rotation tube **61** and the intermediate shaft **62**, and converts the rotating motion of the spiral shaft **631** into the shifting motion of the guide supporting member **81**. Accordingly, the plurality of the fiber supplying guides **80**A and **80**B supported by the guide supporting member **81** can be extended and contracted in the direction approximately perpendicular to the central axis Ra of the liner **1**.

Further, the fiber supplying guides **80**A of the first helical head **43** and the fiber supplying guides **80**B of the second helical head **44** can be extended and contracted with amount and timing of extension and contraction being different therebetween. The amount and timing of extension or contraction of the fiber supplying guides **80**A of the first helical head **43** is controlled by the controller C controlling the rotation direction, the amount of rotation, and the rotation timing of the electric motor **91**. The amount and the timing of extension and contraction of the fiber supplying guides **80**B of the second helical head **44** is controlled by the controller C controlling the rotation direction, amount of rotation, and the rotation timing of the electric motor **92**.

The rotation mechanism **70** makes the fiber supplying guides **80**A and **80**B rotate around the respective axes of the fiber supplying guides **80**A and **80**B. The rotation mechanism **70** mainly includes a rotation tube **71**, an intermediate shaft **72**, and a driving shaft **73**. The rotation mechanism **70** of the first helical head **43** is driven by an electric motor **93** serving as a driving unit that changes an amount of rotation of the fiber supplying guides **80**A. The rotation mechanism **70** of the second helical head **44** is driven by an electric motor **94** serving as a driving unit that changes an amount of rotation of the fiber supplying guides **80**B.

The rotation tube **71** is an annular member having an internal gear formed on an inner peripheral surface thereof. The rotation tube **71** is coaxially arranged around the central axis Ra of the liner **1**, and rotated by the electric motors **93** and **94**.

The intermediate shaft **72** is a member that transmits the rotation of the rotation tube **71** to the driving shaft **73**. A pinion gear disposed on the one end of the intermediate shaft **72** meshes with the internal gear of the rotation tube **71**.

Moreover, a bevel gear **75** disposed on the other end of the intermediate shaft **72** meshes with a bevel gear **76** of the driving shaft **73**.

The driving shaft **73** is a spline shaft that transmits the rotation of the intermediate shaft **72** to the fiber supplying guide **80**A, **80**B. As mentioned above, the bevel gear **76** disposed on the one end of the driving shaft **73** meshes with the bevel gear **75** of the intermediate shaft **72**. Further, a driving gear that is fit externally around the driving shaft **73** meshes with the gear **83** of the fiber supplying guide **80**A, **80**B. The driving shaft **73** is supported rotatably by the annular member **64** having a cross-sectional shape of a letter "C".

With this configuration, the rotation mechanism **70** transmits the driving power of one of the electric motors **93** and **94** to the driving shaft **73** via the rotation tube **71** and the intermediate shaft **72**, and the fiber supplying guides **80**A and **80**B can rotate about the respective axes of the fiber supplying guides **80**A and **80**B via the respective gears **83** of the fiber supplying guides **80**A and **80**B.

Further, the fiber supplying guides **80**A of the first helical head **43** and the fiber supplying guides **80**B of the second helical head **44** can be rotated with the direction, amount, and timing of rotation being different therebetween. The direction, the amount (orientation of the fiber supplying guide **80**A), and the timing of rotation of the fiber supplying guides **80**A of the first helical head **43** is controlled by the controller C controlling the direction, the amount, and the timing of rotation of the electric motor **93**. The direction, the amount (orientation the fiber supplying guide **80**B), and the timing of rotation of the fiber supplying guides **80**B of the second helical head **44** is controlled by the controller C controlling the direction, the amount, and the timing of rotation of the electric motor **94**.

Next, operations of the fiber supplying guides **80**A and **80**B in the helical winding of the FW apparatus **100** with the above configuration will be described. It is assumed that the liner **1** used in the present embodiment includes a first tubular portion **1**A having a constant radius, dome portions **1**B respectively disposed on both ends of the tubular portion **1**A, and second tubular portions **1**C respectively disposed on ends of the dome portions **1**B. Further, it is assumed that the liner **1** is mounted on the liner conveyance device **20**, and that winding conditions, such as the conveyance speed and rotation speed of the liner **1**, the number of times to convey the liner **1** in a reciprocated manner, a conveyance distance, and the like are inputted to the controller C beforehand by an operator. The control unit C is configured to control the actuation of each of the electric motors **93** and **94** based on the inputted winding conditions, and to control changing the orientation of each of the fiber supplying guides **80**A and **80**B in the following way in response to the winding angle to wind the fiber bundle F around the liner **1** and the winding direction for preventing the fiber bundles F from falling off the fiber supplying guides **80**A and **80**B.

FIG. **6**A and FIG. **6**B are side views showing the state where fiber bundles F are wound in the helical winding around the outer peripheral surface **1**AS of the first tubular portion **1**A. FIG. **7**A is a side view showing the state where fiber bundles F are wound in the helical winding around the outer peripheral surface **1**AS of the first tubular portion **1**A. FIG. **7**B is a diagram illustrating the relationship between the orientation of the fiber supplying guides **80**A and **80**B and the orientation of the fiber bundle F in this state, and is a cross sectional view taken along a line C-C in FIG. **7**A.

An arrow A shown in FIG. **6**A indicates the conveyance direction of the liner **1**, and an arrow B shown in FIG. **6**B indicates that the liner **1** is conveyed in the direction opposite to the conveyance direction in FIG. **6**A. An arrow R in FIG. **6**A and FIG. **6**B indicates the rotation direction of the liner **1**. In the helical winding, the fiber bundles F are wound while the liner **1** is conveyed. Accordingly, the winding direction of the fiber bundle F (hereafter, merely referred to as "winding direction") relative to a direction of the central axis of the liner **1** is opposite to the conveyance direction of the liner **1**. Therefore, in FIG. **6**A, the winding direction of the fiber bundle F is the rightward direction in the drawing, opposite to the direction indicated by the arrow A, and in FIG. **6**B, the winding direction of the fiber bundle F is the leftward direction in the drawing, opposite to the direction indicated by the arrow B.

The winding direction shown in FIG. **6**A is the rightward direction, opposite to the direction indicated by the arrow A in the drawing. In this case, the control unit C controls the rotation direction and the amount of rotation of the fiber supplying guides **80**A and **80**B by controlling the actuation of the electric motors **93** and **94**, thereby controlling the orientation of the fiber supplying guides **80**A and **80**B so as to prevent the fiber bundles F from falling off the fiber supplying guides **80**A and **80**B.

Specifically, in the case of the winding angle and the winding direction shown in FIG. **7**A, as shown in FIG. **7**B, the orientation of the opening portion **87** is made to be opposite to the direction FA in which the fiber bundle F is sent out. Further, in a cross sectional view in FIG. **7**B, the bottom portion **84** is made approximately orthogonal to the direction FA in which the fiber bundle F is sent out.

On the other hand, the wind-up direction shown in FIG. **6**B is the leftward direction opposite to the direction indicated by the arrow B in the drawing. In this case, the control unit C controls the rotation direction and the amount of rotation of the fiber supplying guides **80**A and **80**B by controlling the actuation of the electric motors **93** and **94**, thereby controlling the orientation of the fiber supplying guides **80**A and **80**B so as to prevent the fiber bundles F from falling off the fiber supplying guides **80**A and **80**B.

Specifically, similarly to the case shown in FIG. **6**A, the orientation of the opening portion **87** is made to be opposite to the direction FA in which the fiber bundle F is sent out. Further, in the cross sectional view of the fiber supplying guides **80**A and **80**B, the bottom portion **84** is made to be approximately orthogonal to the direction FA in which the fiber bundle F is sent out (refer to FIG. **7**A and FIG. **7**B).

Next, FIG. **8**A, FIG. **8**B, and FIG. **8**C are side views showing the state where the winding direction of the fiber bundles F is switched while winding the fiber bundles F around the outer peripheral surface **1**CS of the second cylindrical portion **1**C and a cross sectional view showing the relationship between the orientation of the fiber supplying guides **80**A and **80**B and the orientation of the fiber bundles F in the above state.

In FIG. **8**A, the conveyance direction of the liner **1** is the direction indicated by the arrow A, and the winding direction of the fiber bundle F is the rightward direction, opposite to the direction indicated by the arrow A in the drawing. In FIG. **8**B, the conveyance direction of the liner **1** has been switched from the direction in FIG. **8**A to the direction indicated by the arrow B, and the winding direction of the fiber bundle F has been switched to the leftward direction, opposite to the direction indicated by the arrow B in the drawing. FIG. **8**B shows the state immediately after the winding direction of the fiber bundle F has been switched. In FIG. **8**C, as compared with FIG. **8**B, the winding of the fiber bundles F progressed more. The winding position of the fiber bundles F being wound around the liner **1** is changed to be more on the rear side than the position of each of the fiber supplying guide **80**A of the first helical head **43** and the fiber supplying guide **80**B of the second helical head **44** in the winding direction of the fiber bundle F (the direction opposite to the indication indicated by the arrow B).

As shown in FIG. **8**A, FIG. **8**B, and FIG. **8**C, in the case where the winding direction of the fiber bundle F is switched, the direction FA in which the fiber bundles F are sent out, changes gradually. Even in such a case, the control unit C controls the orientation of the fiber supplying guides **80**A and **80**B in response to the gradual change in such a way that the orientation of the opening portion **87** of each of the fiber supplying guides **80**A and **80**B is made to be opposite to the direction FA in which the fiber bundles F are sent out, and that the bottom portion **84** is made to be approximately orthogonal to the direction FA in which the fiber bundles F are sent out.

Thus, in accordance with the winding angle and the winding direction in which the fiber bundles F are wound around the liner **1**, the control unit C controls the orientation of the fiber supplying guides **80**A and **80**B so as to prevent the fiber bundles F from falling off the fiber supplying guides **80**A and **80**B. Accordingly, even if tension is applied on the fiber bundles F, the fiber bundles F do not fall off the fiber supplying guides **80**A and **80**B. Consequently, the fiber bundles F can be wound around the liner **1** with sufficient tension applied to the fiber bundles F.

FIG. **9** is a perspective view showing another example of the fiber supplying guide **80**A. The fiber supplying guide main body **82** is provided with an anti-falling member **88** partially covering the opening portion **87**. With the anti-falling member **88**, even while the winding is stopped and thus no tension is applied to the fiber bundles F during the maintenance of the FW apparatus **100** for example, the fiber bundles F can be prevented from falling off the fiber supplying guide **80**A. The anti-falling member **88** is preferably disposed detachably. Further, as the anti-falling member **88**, for example, a resin tube or a resin tape may be employed.

INDUSTRIAL APPLICABILITY

The filament winding apparatus of the present invention facilitates an operation to make a fiber bundle pass through a fiber supplying guide. Thus, the filament winding apparatus can be provided at low price. Accordingly, the filament winding apparatus of the present invention is industrially useful.

DESCRIPTION OF THE REFERENCE NUMERAL

1 Liner
1S Outer peripheral surface
10 Main base
20 Liner conveyance device
30 Hoop winding device
40 Helical winding device
42 Helical winding support device
43 First helical head
44 Second Helical head
45 Guide supporting device
50 Driving unit
51 Electric motor
52 Worm gear
53 Rack gear
60 Movement mechanism
61 Rotation tube
62 Intermediate shaft
62 Ball screw
70 Rotation mechanism
71 Rotation tube
72 Intermediate shaft
73 Driving shaft
80A, **80**B Fiber supplying guide
81 Guide supporting member
82 Fiber supplying guide main body
83 Gear
84 Bottom portion
86 Side portion
87 Opening portion
88 Anti-falling member
89 Insertion hole
100 Filament winding apparatus
F Fiber bundle
WA Winding angle

The invention claimed is:

1. A filament winding apparatus configured to wind a fiber bundle around a liner, comprising a plurality of fiber supplying guides each being configured to supply a fiber bundle to the liner, wherein

each of the fiber supplying guides includes a bottom portion that guides a wide surface of the fiber bundle, side portions respectively disposed along both sides of the bottom portion, and an opening portion formed between the side portions, and

each of the fiber supplying guides has an approximately U-shaped cross section in a direction orthogonal to an axial direction.

2. The filament winding apparatus according to claim **1**, further comprising:

a driving unit configured to make the fiber supplying guides rotate about an axis; and

a controller configured to change an orientation of each of the fiber supplying guides by controlling the driving unit,

wherein the controller changes an orientation of the fiber supplying guide in accordance with a winding angle and winding direction in which the fiber bundle is wound around the liner, in such a manner that the fiber bundle does not fall off the fiber supplying guide.

3. The filament winding apparatus according to claim **1**, wherein an anti-falling member configured to partially cover the opening portion is disposed detachably.

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